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A REVIEW OF THE AMORPHOUS MINERALS

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Mineralogists generally have neglected the study of naturally occurring amorphous substances. None of the modern mineralogical textbooks or treatises give an adequate treatment of the amorphous state or condition. Crystals are treated at great length, but the amorphous state is usually given only a paragraph or two.[1]

The reasons for this neglect on the part of mineralogists are apparent. Crystals, with their great variety of form and physical properties, offer a more attractive field for study. Crystalline material so greatly predominates over amorphous material in the earth's outer shell that it is regarded as typical of the solid state. In selecting material for chemical analysis crystals are selected as far as possible, for crystallization is Nature's great method of producing pure inorganic substances.

While the mineralogist is primarily a crystallographer and while crystallography is left largely in the hands of the mineralogist, we need to be reminded that mineralogy and crystallography are by no means synonymous. Crystallography deals with crystals produced in the laboratory as well as with mineral crystals. Mineralogy deals with all homogeneous, naturally occurring, inorganic substances, whether crystalline or amorphous. The two fields overlap but do not coincide.

In view of the recent advances in colloid chemistry, the mineralogist can no longer be excused for his neglect of the study of the amorphous state. Although the science of colloid chemistry has been developed largely by chemists, Breithaupt, one of the early mineralogists and perhaps the greatest of the old natural-history school of mineralogists, recognized colloids under the name porodine substances as early as 1817.[1] He called attention to the fundamental differences between the crystalline and amorphous conditions and divided amorphous substances into two groups: the hyaline (glasses) and porodine ("guhren" or gels). Breithaupt knew of the researches of Graham before the publication of the latter's discovery of dialysis and stated that his group of "guhren" was identical with the laboratory products of Graham.

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[1] Knop, however, in his *System der Anorganographie* (Leipzig, 1876), and Doelter, in his *Physikalisch-chemische Mineralogie* ((Leipzig, 1905), both treat the amorphous state at some length.

The application of colloid chemistry to mineralogy has been pointed out by Cornu and others in a series of papers published in 1909[2], and more recently Marc and Himmelbauer[3] have contributed an excellent summary and bibliography of the whole subject.

CONFUSION OF THE TERMS AMORPHOUS AND COLLOIDAL

While the study of the amorphous condition involves a study of the colloidal or "dispersed" state, the terms amorphous and colloidal are not synonymous. Amorphous is the broader term. Ordinary glasses are amorphous but not colloidal, although some varieties of glass may be colloidal (e.g., opalescent glass). Colloids are microheterogeneous systems made up of two phases, one dispersed through another.

Most of the amorphous minerals are hardened hydrogels. The water present is usually considered to be adsorbed water. It may be adsorbed water when the colloid is first formed (even this fact is doubted by Robertson),[4] but after hardening, the water may be present in solid solution.[5] Hyalite opal, for example, is apparently a microhomogeneous substance, and there is no reason why it may not be looked upon as a true solution of water in silica. Hence it is possible, and even probable, that the mineral hydrogels are not, properly speaking, colloids, but only colloidal in origin.

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[1] Cornu, *Zeit. f. Chem. u. Ind. d. Kolloide*, IV (1909), 300–4; Hunt, *Systematic Mineralogy*, New York, 1891, p. 10.

[2] *Ibid.*, IV, 15, 89, 187, 188, 189, 275, 285, 291, 295, 298, 300, 304, 306.

[3] *Fortschritte der Min., Krist., u. Petrog.*, III (1913), 11, 32.

[4] *Zeit. f. Chem. u. Ind. d. Kolloide*, III (1908), 49.

[5] The fluorin content of collophone mentioned later in this paper is an argument in favor of the solid solution theory of hydrogels.

Wolfgang Ostwald says: "The colloid solutions . . . . should always be meant when colloids in general are under discussion,"[1] and also "when we speak of a 'colloid' we nearly always mean one in this condition, in other words, one in the *sol condition*."[2]

Bütschli described the gels as possessing a honeycomb structure, but according to Bachmann[3], this is simply an optical effect. By means of the ultramicroscope the latter proved that the structure of the solid gel of silica is extraordinarily fine and for the most part amicroscopic (i.e., made up of amicrons).

Whether the hardened gels are colloidal or not, we are safe in calling them amorphous.

There is a tendency on the part of some modern mineralogists to use the term colloid, not only for the hydrogel minerals, but also for microcrystalline substances of colloidal origin. The recognition of colloidal structures in the study of minerals, rocks, and ores[4] is important, but the fundamental differences between amorphous and crystalline minerals should not be lost sight of. In the identification of minerals the mineralogist is concerned with amorphous and crystalline substances, and not primarily with colloidal structures. The confusion of the terms colloidal and amorphous is apparent in a number of recent mineralogical papers. For example, Cornu[5] classifies chrysocolla as the "gelform" of dioptase, when, as a matter of fact, chrysocolla is crystalline. Its amorphous equivalent is another mineral recognized in this paper for the first time. The use of the term *metacolloid* proposed by Wherry[6] for microcrystalline substances of colloidal origin will do much to clear up the difficulty. Cornu's term "gelform" is ambiguous, and as an illustration let us take the silica minerals. Opal is listed as the "gelform" of chalcedony by Cornu and chalcedony as a "krystalloidform." But both of the minerals have colloidal characteristics, and if we treat them as Cornu treats chrysocolla they would both be considered as colloidal or "gelforms" of quartz. In the case of silica minerals, for example, ambiguity is avoided if we call opal amorphous silica and chalcedony metacolloidal silica.[1]

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[1] *Handbook of Colloid Chemistry* (Eng. trans. of 3d edition by Fischer, 1915), p .24.

[2] *Ibid.*, p. 40.

[3] *Zeit. f. anorg. Chemie*, LXXIII (1911), 125.

[4] For a discussion of colloidal structures in ores see Krusch, *Zeit. f. prakt. Geol.*, 21. Jahrgang (1913), 506–13.

[5] *Zeit. f. Chem. u. Ind. d. Kolloide*, IV (1909), 17.

[6] *Jour. Wash. Acad. Sci.*, IV (1914), 112.

CRITERIA FOR THE RECOGNITION OF AMORPHOUS SUBSTANCES

To the mineralogist is committed the task of describing and defining all of the definite, homogeneous, naturally occurring substances, whether they be crystalline or amorphous.

How may amorphous substances be distinguished from crystalline substances? On the face of it this seems to be easy, but, as a matter of fact, the problem is often very difficult. Crystalline substances may be defined as those having discontinuous vectorial properties[2] and amorphous substances as those not having such properties, but the actual determination of whether a given substance has discontinuous vectorial properties or not may be very difficult.

From the standpoint of physical chemistry amorphous solids are liquids. Now, the shape of a liquid unaffected by gravity or other external influence is spherical, and so we often find the hydrogel minerals in spherical, botryoidal, reniform, stalactitic, and mammillary forms. These forms intergrade, so that one is often at a loss to know which term to use. I therefore propose the term *colloform* for the rounded, more or less spherical, forms assumed by colloidal and metacolloidal substances in open spaces. Some crystalline, not merely microcrystalline, minerals, such as smithsonite, also occur in colloform crusts, and it should be emphasized that this term refers only to the shape or form, and not to the condition of the material.

Colloform minerals may be either amorphous or crystalline, while, on the other hand, minerals occurring in euhedral crystals may be amorphous alteration products of original crystals, for example, malacon, which is a pseudomorph after zircon. Yttrotantalite, thorite, allanite, gadolinite, homilite, and yttrocrasite all occur in euhedral tetragonal, orthorhombic, or monoclinic crystals.

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[1] Chalcedony may be either a distinct mineral or a variety of quartz.

[2] Friedel, *Leçons de Cristallographie* (Paris, 1911), p. 2.

Yet in many cases the material is optically isotropic and we apparently have the amorphous equivalents of these minerals occurring as pseudomorphs after the original crystalline minerals. The typical structures of crystalline aggregates, such as fibrous, lamellar, etc., do not necessarily indicate crystallinity, for these structures may be remnants of an original crystalline condition, now consisting of amorphous material. Pyrolusite, for example, is probably an amorphous manganese dioxid produced by the dehydration of crystalline manganite, which accounts for its fibrous structure.

In the absence of cleavage and other direct proofs of crystallinity we must rely largely upon optical tests for transparent and translucent minerals. A serious difficulty confronts us here, for isometric crystals, as well as amorphous solids, are optically isotropic, and anhedral isometric crystals without cleavage may be confused with amorphous substances of similar appearance.

Still another difficulty lies in the fact that many amorphous substances are doubly refracting. This is especially true of colloform crusts, and the double refraction here is due to strains set up in the hardening of the gel. The hyalite variety of opal practically always shows double refraction. The birefringence of an amorphous mineral is usually very weak, but in some cases it reaches an appreciable amount. In a specimen of phosphorite from Lassa Island containing both dahllite and collophane the double refraction of colloform bands of amorphous collophane is greater than that of the corresponding crystalline dahllite. Double refraction due to strain can usually be distinguished from the double refraction of optically anisotropic crystalline substances by its lack of uniformity.

For opaque minerals etching experiments are perhaps the most satisfactory tests to try in the absence of evident crystalline structure. Tolman[1] has recently described metacolloidal chalcocite. The determination was made by examining polished surfaces etched by nitric acid with the metallographic microscope.

From the foregoing discussion it is evident that in many cases the scalar properties must be used to distinguish amorphous and crystalline substances, and it should be emphasized that the optical properties are also scalar for isometric crystals.

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[1] *Bull. 110 Am. Inst. Min. Eng.*, 1916, p. 410.

Among the scalar properties are specific gravity, specific heat, fusibility, solubility, and also the index of refraction for both isometric crystals and amorphous substances. Now, any one of these properties is somewhat different[1] for an amorphous substance and the corresponding crystalline substance, i.e., one with the same, or approximately the same, chemical composition. The solubility and fusibility are not easy to determine accurately, and this is often true of the specific gravity.

The determination of the index of refraction, and not the presence or absence of double refraction, furnishes the most generally available means of identifying a given amorphous mineral. Irregular grains of garnet in the form of sand, for example. are identified as garnet, not because it proves to be crystalline, but because of the isotropic character, high index of refraction, absence of cleavage, pink color, etc. We know it to be crystalline simply because it is garnet. An amorphous mineral corresponding to garnet would have a lower index of refraction. It might be difficult to prove that such a mineral is amorphous in the first place, but if this fact were once established the mineral could be distinguished from garnet or, more accurately speaking, from one of the members of the garnet group by its index of refraction. The index of refraction, however, is sometimes misleading. For example, lussatete is a fibrous variety of silica probably identical with chalcedony, yet it has the index of refraction of opal. The explanation is that minute fibrous aggregates of chalcedony have gradually crystallized out of an amorphous mass of opal.

Many of the amorphous minerals may be distinguished from their crystalline equivalents by the presence of water, which seems to be almost universally present in the amorphous minerals.

THE GENERALLY RECOGNIZED AMORPHOUS MINERALS

Comparatively few amorphous minerals are recognized in standard works on mineralogy. In Dana's *System of Mineralogy* (6th edition, 1892) with its three appendixes (1904, 1909, 1915), for example, approximately one thousand minerals are given the rank of distinct species, and of these only seventeen[1] are listed as amorphous. Some of these are probably synonyms and some are undoubtedly crystalline. Of the amorphous minerals described since the appearance of Dana's *System* none has been given the rank of mineral species in the appendixes of that work.

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[1] See Knop, *op. cit.*, p. 8.

The principal reason why so few amorphous minerals are listed is because the amorphous equivalents of crystalline minerals, with the single exception of opal, are not recognized as distinct mineral species. We find, for example, crystalline cupric oxid (tenorite) united with amorphous cupric oxid (melaconite). Amorphous limonite is united with its fibrous and crystalline equivalent. Crystalline and amorphous ferric oxid are both included under the name hematite.

ARE AMORPHOUS MINERALS TO BE RECOGNIZED?

The chemical composition of most amorphous minerals is not as definite as that of the average crystalline mineral, but since the discovery of the variability in the composition due to solid solution of such well-crystallized minerals as pyrrhotite and nephelite, we can no longer insist that the term "mineral species" be confined to those of definite chemical composition. Many of the amorphous minerals approach closely in chemical composition the corresponding crystalline mineral, as was first emphasized by Cornu,[2] who called these minerals "pseudo-stöchiolithe." Practically all the amorphous minerals contain water, even if the corresponding crystalline minerals are anhydrous, but this water or the excess water over that present as hydrion or hydroxyl is probably not essential. The myeline from Rochlitz, Saxony, for example, is probably the amorphous equivalent of kaolinite, yet it contains practically the same amount of water.

Some of the amorphous minerals are definite enough to be recognized, though we must, of course, allow more latitude in chemical composition and physical properties than with crystalline minerals. The physical properties of many of the amorphous minerals can be determined as completely as those of many of the massive non-cleavable isometric minerals, for in the absence of cleavage and crystal form all the available properties for determination are scalar.

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[1] These are opal, collophanite, bindheimite, szmikite, deweylite, genthite, garnierite, spadaite, saponite, glauconite, cimolite, montmorillonite, allophane, collyrite, schrötterite, chloropal, and hisingerite.

[2] *Zeit. f. Chem. u. Ind. d. Kolloide*, IV (1909), 15, 89.

Most authorities admit an amorphous mineral to the full rank of species if it has no crystalline equivalent, but discard those with crystalline equivalents. This, I believe, is inconsistent, and it would seem more logical to refuse admittance to an amorphous mineral until its crystalline modification is described. It is also inconsistent to recognize opal and not the other amorphous equivalent of crystallized minerals. Opal is not a definite hydrate of silica, but is silica with dissolved or adsorbed water. Other amorphous minerals also contain dissolved or adsorbed water and bear the same relation to crystalline equivalents that opal does to quartz. As shown by von Weimarn,[1] the colloidal condition is a general property of matter. No one can doubt that the amorphous and crystalline conditions are fundamentally different. Any given substance possesses a different energy content in these two conditions.

If it is admitted that the properties of amorphous minerals are sufficiently distinct. and we admit this when we use such names as opal, pitticite, allophane, etc., we must assign the known amorphous equivalents of crystallized minerals the rank of independent mineral species. The first step in this direction was taken, I believe, by Cornu[2] in 1909. He introduces the names kliachite, stilpnosiderite, gelvariscite, gelfischerite, geldiadochite, gelpyrophyllite, etc., as names of the amorphous equivalents of hydrargillite, limonite, variscite, fischerite, diadochite, and pyrophyllite, respectively. This, in my opinion, is one of the important advances in systematic mineralogy. Although sound from the standpoint of physical chemistry, this principle has not been generally adopted. We are conservative, and even desirable changes are slow in adoption, but it seems strange that such names as cliachite or kliachite are not adopted when so many new names of mere varieties or mixtures of older minerals[1] are apparently welcomed.

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[1] *Zur Lehre von den Züstanden der Materie* (Leipzig, 1914).

[2] *Zeit. f. Chem. u. Ind. d. Kolloide*, IV (1909), 15.

NAMES FOR AMORPHOUS MINERALS

If it be granted that amorphous minerals deserve recognition, then names of some kind are necessary. Are these to be distinctive names or modifications of the names of the corresponding crystalline minerals? Cornu used the prefix "gel" with the crystalline modification (e.g., gelvariscite, for the amorphous equivalent of variscite). Tućan[2] employed a similar device, except that "gel" came after the root name instead of before it (e.g., hematogelite for colloidal ferric oxid). Wherry[3] proposed that the Greek letter κ (the abbreviation of κoλλα) be used as a prefix to the crystalline compound (e.g., κ-limonite for stilpnosiderite).

A serious objection to all these proposals lies in the fact that the amorphous mineral is not related to one polymorphous modification any more than to another. Most mineral substances are known in but one crystalline modification, but other modifications may be found in the future, as polymorphism seems to be a general phenomenon of nature.

The name of any crystalline mineral connotes certain crystal forms and physical properties as well as a given chemical composition. It is absurd, then, to speak of amorphous calcite or amorphous aragonite. The proper term to use is amorphous calcium carbonate.

Distinctive names, then, are necessary, or at least advisable, for the amorphous equivalents of crystalline as well as for the other amorphous minerals. As an illustration of the need of distinctive names for amorphous minerals, let me cite the case of variscite. Cornu, in 1909, called its amorphous equivalent gelvariscite, but Schaller has recently described lucinite, a dimorph of variscite.

Few new names are necessary, for varietal and other discarded names may be used. In this paper I have recognized about twenty of the best-defined amorphous minerals and have found it necessary to introduce but two new names. In the future other new names will be necessary, but their introduction will be gradual. It is not desirable to recognize all amorphous mineral substances, but only those that will stand the test of a critical examination, and usually only those that are found in a number of localities. I would emphasize especially the recognition of those with crystalline equivalents, for then we have a comparison of properties which are especially useful in determination.

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[1] See paper by the author, "The Nomenclature of Minerals," *Trans. Am. Phil. Soc.*, LII (1913), 606–15.

[2] *Centralblatt f. Min. Geol. u. Pal.*, 1913, p. 68.

[3] *Ibid.*, pp. 517–18.

SOME OF THE PROMINENT AMORPHOUS MINERALS

I now propose to describe and discuss what seem to be the better established amorphous minerals, with especial emphasis upon those that I have been able to study in more or less detail.

Amorphous carbon (schungite, mineral charcoal).—Graphite is the hexagonal modification of carbon, and the so-called amorphous graphite is probably compact, dense graphite in a fine state of division. Graphitite and graphitoid, according to Weinschenk,[1] are simply varieties of graphite.

Schungite, described by Iostranzeff from near Schunga, Government Olenez, Russia, is an amorphous modification of carbon, for when treated with a mixture of potassium chlorate and nitric acid it is soluble and is not, like graphite, converted into the yellow, scaly substance called graphitic acid.

Amorphous sulfur (sulfurite).—Besides the common orthorhombic, and the rare monoclinic, sulfur found at a few localities amorphous sulfur also probably occurs in nature. Rinne[2] has proposed the name sulfurite for naturally occurring amorphous sulfur. He describes an arsenical variety (arsensulfurite) which occurs as amorphous crusts on andesite.

Xanthochroite $CdS(H_2O)_x$? (greenockite in part).—The cadmium sulfid which occurs as a thin incrustation on sphalerite is amorphous, as has been recognized by Lacroix and by Christomanos. It is usually called greenockite, but the original cadmium sulfid first described from Scotland and found in but few other localities is hexagonal. A new name is necessary for amorphous cadmium sulfid and I propose to call it *xanthochroite* (Greek *xanthos*, yellow, *chroa*, color).

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[1] *Zeit. f. Kryst. u. Min.*, XXVIII (1897), 291.

[2] *Centralblatt f. Min. Geol. u. Pal.*, 1902, p. 499.

This mineral has recently been found near Topaz, Mono County, California, where it occurs as a thin coating on massive magnetite. With the magnetite is associated sphalerite, and the xanthochroite is doubtless a secondary mineral derived from sphalerite. It varies from yellow to orange in color and is almost opaque when examined with the microscope. There is no evidence of crystallization or double refraction. It is soluble in hydrochloric acid and is reprecipitated by hydrogen sulfid. It is immediately darkened by copper sulfate solution, and this will probably distinguish it from crystalline greenockite.

Hydrotroilite. $FeS(H_2O)_x$.—The black slime found in inland seas and in some moist sands and clays is colloidal and amorphous ferrous sulfid. It has been described from Hadishibey Liman in Southern Russia by Sidorenko[1] and the name hydrotroilite given to it. As troilite is a synonym of pyrrhotite, the name is not a very fortunate one, but it has priority.

I am indebted to Mr. G. A. Waring, of the United States Geological Survey, for a black slimy deposit from the Kruzgekampa Spring, 60 miles north of Nome, Alaska. This consists of a black, opaque substance mixed with sand grains and diatoms. The black substance is hydrotroilite. It is soluble in cold hydrochloric acid with the evolution of hydrogen sulfid. The solution gives tests for ferrous iron, and with ammonia a black precipitate is obtained.

Wherry[2] proposes to call the melnikowite of Doss[3] κ-pyrite, but melnikowite is microcrystalline (metacolloidal) FeS_2 and not amorphous. This is a serious objection to Wherry's scheme of nomenclature.

Opal. $SiO_2(H_2O)_x$ (lardite).—Opal is a typical amorphous hydrogel and is unique in that, until Cornu's work in 1909, it was the only amorphous equivalent of a crystallized mineral generally recognized as a distinct species. The properties of opal are so well known that a description is unnecessary. Attention, however, should be called to the fact that hyalite opal, the purest and most typical form of opal, usually shows double refraction due to strain.

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[1] For reference to original article see *Neues Jahrb. f. Min. Geol. u. Pal.*, II (1902), ref. p. 397.

[2] *Central. f. Min. Geol. u. Pal.*, 1913, p. 518.

[3] *Neues Jahrb.*, Beil. Bd. XXXIII (1912), 689–93.

(*Lechateliérite*) ?—The amorphous constituent of fulgurites and of some inclusions in volcanic rocks has recently been named lechateliérite by Lacroix.[1] This material approaches silica glass in composition and is also very similar to opal in properties. The only difference between lechateliérite and opal is due to their previous history, but, as Miers says, ". . . . the essential character of a mineral, moreover. is quite independent of its source or previous history."[2] Yet these two substances are so different in occurrence and origin that one feels inclined to consider them as distinctive minerals. Then we are confronted with the question whether we are ever to recognize more than one amorphous mineral for a given crystalline equivalent or not.

Now, lechateliérite is a glass and may be considered along with other natural glasses as a mineraloid (see p. 540) rather than as a mineral proper. As an argument for this, I give the results of my examination of a fulgurite found in the sand dunes along Lake Michigan in Van Buren County, Michigan, and obtained from Ward's Natural Science Establishment. The fulgurite is a hollow tube of glass with small grains of white sand adhering to the exterior surface. The sand grains are quartz and orthoclase. The glass is colorless and perfectly isotropic with an index of refraction of 1.462±0.003. It is fusible on the edges and gives a small amount of water in the closed tube. From these tests it can be seen that the glass is not pure silica, but a glass high in silica. The lechateliérite described by Lacroix is almost pure silica, as its index of refraction is 1.458. Whether a distinctive name is desirable or not, the glass of fulgurites may be considered simply as a mineraloid, which approaches pure silica glass in composition.

Hydrocuprite. $Cu_2O(H_2O)_x$ (hydrocuprite, ziegelite,ziguéline, tile-ore).—Two kinds of cuprous oxid occur in nature: (1) isometric cuprite and (2) amorphous tile-ore, for which the name hydrocuprite may be used. Werner considered *rothkupfererz* and *zeigelerz* as co-ordinate. Beudant used the name ziguéline as a species name for cuprous oxid. Hydrocuprite was described by Genth[1] as an orange-yellow to orange-red, amorphous raglike coating on magnetite from Cornwall. The same substance has been noted by Lacroix on cuprite from Chessy, France, and by Sandberger, mixed with cuprite, from Schapbach, Baden. According to Schaller[2] the supposed vanadium ocher from Lake Superior is hydrocuprite (or possibly cuprite).

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[1] *Bull. Soc. Fran. de Min.*, XXXVIII (1915), 182–86.

[2] *Mineralogy*, 1902, p. v.

I have observed what I consider to be amorphous cuprous oxid in specimens from the Lowell mine, Bisbee, Arizona; the Poderosa mine, Collahuasi, Chile; and an unknown locality. The hydrocuprite occurs as a massive brick-red mineral associated with cuprite. Under the microscope it appears as an orange-colored, almost opaque substance in contrast to the dark-red translucent cuprite. No very satisfactory optical tests can be made on account of the opacity, but in a few spots the orange-colored mineral is isotropic as well as the cuprite.

On account of the optically isotropic character of both of these minerals the closed-tube test may prove useful. Hydrocuprite contains water, but it is not a definite hydrate, as the name implies.

Melaconite. $CuO(H_2O)_x$ (tenorite in part, melanochalcite).—Dana united the crystalline tenorite and amorphous melaconite under the name tenorite, but they should be separated. Crystalline tenorite is a very rare mineral, known only from Vesuvius, Cornwall, and Keweenaw Point, Michigan, but the amorphous melaconite is a fairly common mineral in the oxidized zone of copper mines. It is a black, massive mineral and occasionally occurs in colloform crusts. In fragments it is black and opaque, but is usually translucent brown and isotropic on the thin edges. In addition to cupric oxid and water melaconite also contains silica, the carbonate radical, and often manganese oxid.

Melanochalcite, described by Koenig as a copper salt of silicocarbonic acid, is undoubtedly melaconite. Kraus and Hunt[3] decide that melanochalcite is a mechanical mixture of tenorite, malachite, and chrysocolla. While the two latter minerals may sometimes be associated with it, homogeneous melaconite free from mechanical impurities also gives tests for the carbonate radical and silica. Melaconite is either an adsorption compound or a solid solution of cupric oxid and water with silica, carbonate radical, and often manganese dioxid.

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[1] *Preliminary Report on the Mineralogy of Pennsylvania,* Pennsylvania Second Geol. Surv., 1875, p. 46.

[2] *Am. Jour. Sci.* (4), XXXIX (1915), 404.

[3] *Ibid.,* (4), XLI (1915), 211–14.

Hematite. $Fe_2O_3(H_2O)_x$ (hydrohematite, turgite, hematogelite).—Two varieties of ferric oxid are generally recognized, a crystalline one and a massive or earthy-red one. Haüy and Werner respectively considered these as distinct minerals under the names fer oligiste, fer oxydé rouge and eisenglanz, rotheisenstein. They were united by Hausmann, and he has been generally followed by other mineralogists. The red, earthy varieties of ferric oxid, such as the oölitic Clinton ore and the soft hematites from the Mesabi range, are amorphous and should be separated from the crystalline ferric oxid. The amorphous ferric oxid may be distinguished from the crystalline mineral by the fact that it contains a small amount of water.

Turgite is usually considered to be $2Fe_2O_3 \cdot H_2O$, but it is probably not a definite hydrate. Turgite often occurs in colloform crusts. It sometimes shows a fibrous structure, but this is probably because it is a dehydration product of limonite and retains its structure. In fragments turgite is very dark red, sometimes isotropic and sometimes birefringent. The double refraction may be due to strain. Turgite is essentially identical with amorphous hematite.

Specularite, now used as a varietal name by many mining geologists, may be used as a specific name for crystalline ferric oxid, and hematite then may be used exclusively for amorphous ferric oxid.

Limonite. $Fe_4H_6O_9(H_2O)_x$(?) (stilpnosiderite, melanosiderite, limnite, esmeraldaite, xanthosiderite ?).—Leaving göthite out of consideration, hydrous ferric oxid with a yellow-brown streak occurs in two distinct forms, a crystalline fibrous form and an amorphous massive form. Under the microscope the former appears as crystalline fibers with parallel extinction, and the latter is optically isotropic and usually structureless. As Cornu suggests, these two forms should have distinctive names. He used limonite for the crystalline mineral and stilpnosiderite for the amorphous one, but in view of the fact that the simpler name limonite is so well established for the common and widely distributed brown hydrated iron ore of surface origin it seems advisable to retain the name limonite for the amorphous mineral. Limonite in this restricted sense has priority over stilpnosiderite, for it was used by Hausmann in 1813, while the name stilpnosiderite was introduced by Ullmann in 1814 and usually has been used as a varietal name for *eisenpecherz.*

A new name is necessary for the crystalline mineral with the composition $Fe_4H_6O_9$, but in view of the fact that the mineral hydroxids of irod are being investigated by the Geophysical Laboratory no suggestion is offered at present.

The melanosiderite of Genth is not an iron silicate, but limonite with dissolved or adsorbed silica. The water content of the amorphous ferric oxids is variable, and so it is probable that xanthosiderite, limnite, and esmeraldaite are not definite hydrates, but are all simply varieties of limonite.

Stibiconite. $Sb_2O_4(H_2O)_x$ (stibianite, stiblith, stibioferrite, volgerite).—The most common alteration product of stibnite is the amorphous mineral stibiconite. It is probably colloidal antimony tetroxid with adsorbed or dissolved water and not a definite hydrate. The existence of crystalline antimony tetroxid is doubtful, for no accurate description of cervantite has ever been made. Tenné and Calderon state that much of the supposed Spanish cervantite is valentinite.

Cliachite. $Al_2O_3(H_2O)_x$ (bauxite in part, wocheinite, sporogelite, alumogel, shanyavškite).—Bauxite should be used as the name of a certain type of rock and not as a mineralogical term. It was so regarded by Dufrenoy, who introduced the name in 1845. He has been followed by Tućan, Tschermak, and Lacroix. Dittler and Doelter, however, use bauxitite for the rock name.

The principal constituent of bauxite is an amorphous mineral called cliachite (kliachite) by Cornu, who revived the name used by Breithaupt.

The crystalline mineral corresponding to cliachite is hydrargillite or gibbsite. This occurs to a minor extent in pisolitic bauxite and also in some clays, but in the "granitic type" of bauxite from central Arkansas[1] hydrargillite is the principal mineral.

The composition of bauxite is usually given as $Al_2O_3 \cdot 2H_2O$, but, as in the other amorphous minerals, the water content of cliachite is variable. In the purest of the Georgia bauxites the ratio of Al_2O_3 to H_2O is very close to 1 to 3, according to Watson.[2]

An amorphous mineral from India described by Warth[3] under the name gibbsite has the composition $Al_2O_3 \cdot 3H_2O$ and is probably cliachite.

Shanyavskite, an amorphous mineral with the composition $Al_2O_3 \cdot 4H_2O$, is probably essentially the same as cliachite.

I have examined several specimens of cliachite and have found the index of refraction to be 1.570 ± 0.005.

Pyrolusite. $MnO_2(H_2O)_x$.—Pyrolusite is probably an amorphous manganese dioxid corresponding to crystalline polianite. The fibrous structure is due to the fact that it is pseudomorphous after manganite. It always contains a small amount of water.

Psilomelane. Formula doubtful (wad, lithiophorite, asbolane, lampadite).—Lacroix says that psilomelane is crystalline. There may be crystalline equivalents of psilomelane, such as hollandite and romanèchite, but most specimens of psilomelane show no indication of crystalline structure and are doubtless amorphous. Psilomelane is probably a salt of some manganese acid and not simply an oxid of manganese. Along with water it may contain BaO, CaO, MgO, Fe_2O_3, Al_2O_3, K_2O, Na_2O, Li_2O, CoO, and CuO. A specimen from near Sodaville, Nevada, presented to me by Mr. L. B. Spencer, is said to contain SnO_2 and WO_3.

Collophane. $3Ca_3(PO_4)_2 \cdot Ca(CO_3,F_2)(H_2O)_x$ (apatite in part, collophanite, fluocollophanite, quercyite, nauruite).—The principal constituent of phosphorite or so-called phosphate rock is not massive apatite, but an amorphous substance which is identical with the kollophan of Sandberger. Collophane[1] is a calcium carbonophosphate approaching the formula given above. When the mineral was first described, the calcium carbonate present was thought to be an impurity and so was deducted from the analysis. The chemical composition, as with most amorphous minerals, is variable and somewhat uncertain, because it is difficult to distinguish mechanical impurities from essential constituents.

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[1] Mead, *Econ. Geol.*, X (1915), 41.

[2] *Am. Geol.*, XXVIII (1901), 25.

[3] *Mineral. Mag.*, XIII (1902), 172.

Fluorin is present in some specimens, and Lacroix uses the name fluocolophanite for varieties rich in fluorin. Artini[2] describes an amorphous mineral in the phosphorites of Es Salt, Palestine, which he says is a fluorcollophanite near fluorapatite in composition. I have found that fossil bones consist of the mineral collophane, and Carnot[3] has shown that the fluorin content of fossil bones increases with the geological age of the bones. If there is an amorphous equivalent of fluorapatite, should a distinctive name, such as fluocollophane, be used for it? As more latitude must be allowed in the chemical composition of amorphous minerals than in the crystalline minerals, it hardly seems advisable to use more than one name (collophane) for amorphous equivalents of minerals of the apatite group. The fluorin determination is not an accurate one, and fluorin in analyses of the phosphorites may be due to fluorite or residual apatite.

Collophane is a massive mineral and often has oölitic or concretionary structure. In cavities it appears in colloform crusts and often resembles opal. The color is sometimes white, but is usually yellow, brown, or black, and is probably due to an organic pigment.

Collophane is isotropic in part, but frequently shows double refraction. In a specimen of phosphorite from Lassa Island the double refraction of the colloform collophane is greater than that of the accompanying fibrous dahllite. I have examined specimens of fossilized bones consisting of collophane which shows an appreciable amount of double refraction. The double refraction is variable from spot to spot, and the result is a characteristic wavy extinction.

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[1] Dana changed kollophan to collophanite, but since the name has not come into general use it is preferable to use the English equivalent of the original, which is a simpler and more euphonious name. Another argument is that collophanite may be confused with colophonite, a variety of garnet.

[2] Abstract in *Zeit. f. Kryst. u. Min.*, LV (1915), 320.

[3] *Ann. de Mines* (9), III (1893), 155.

In view of these facts the safest method of distinguishing collophane from dahllite is usually by means of the index of refraction. I have determined the index of refraction of collophane from many localities and have found that it usually varies from 1.57 to about 1.61,[1] while that of dahllite varies from about 1.61 to 1.63. With high magnification dahllite shows a fabrous structure which is lacking in collophane.

Like dahllite, collophane is soluble in hot nitric acid with effervescence, but in the closed tube it gives a great deal of water while dahllite gives little or none.

The quercyite of Lacroiz[2] is collophane and not a mixture of dahllite and collophane. I have examined a specimen of a banded calcium carbonophosphate mineral labeled "Hydroapatite, Marseilles, France," which is identical with Lacroix's quercyite. The doubly refracting layers of my specimen and probably of the specimens figured by Lacroix (*op. cit.*, p. 580) are collophane and not dahllite. In support of this view it may be mentioned that the index of refraction (1.598±0.002 in my specimen, but Lacroix gives 1.608) is too low and the water content (3.2 to 6.0 per cent) too high for dahllite. Double refraction is by no means a proof of crystallinity. Lacroix also mentions the fact that the fibers of quercyite lack the individuality of those of dahllite (and staffelite), which is a good argument in favor of its being collophane.

Monite from Mona Island in the West Indies is also a variety of collophane. It is a white, earthy, massive mineral which, under the microscope, is largely isotropic with small doubly refracting spots. The index of refraction is 1.631±0.001, a little higher than for most specimens of collophane. Monite effervesces vigorously in hot nitric acid, so that the carbonate radical was overlooked in Shepard's analysis. In the closed tube it gives abundant water. Monite also contains the sulfate radical, but this is not present as gypsum, as Shepard thought, for the mineral is homogeneous except for minute crystals of monetite and colloform crusts of dahllite. The sulfate radical probably replaces part of the carbonate radical. Phosphorites from Idaho and South Carolina also contain the sulfate radical.

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[1] The fluorcollophanite described by Artini (*loc. cit.*) has an index of refraction of 1.630.

[2] *Mineralogie de la France*, IV (1910), 579.

Nauruite described by Elschner[1] from the island of Nauru is another synonym of collophane. It is a yellow to brown resinous mineral occurring as agate-like layers in cavities of phosphorite. The formula given is $3Ca_3P_2O_8 - \left\{ \begin{matrix} Ca(OH)_2 \\ CaF_2 \end{matrix} \right\}$. The analyses of the Nauru phosphorites all show calcium carbonate, and specimens of typical nauruite kindly furnished by Mr. Elschner effervesce vigorously in hot nitric acid. Under the microscope the Nauru collophane shows banded spherulitic structure and weak double refraction. The index of refraction is 1.597 ± 0.001, which proves that the mineral is not dahllite in spite of its birefringence. The double refraction is variable and is lost upon heating.

I have examined thin sections of phosphorites or so-called phosphate rocks from Florida, South Carolina, Tennessee, Kentucky, Idaho, Nauru, Fanning Island, Ocean Island, Lassa Island, and Clarendon, New Zealand, and have found amorphous collophane to be the principal constituent of all of them. It is often accompanied by dahllite. It seems strange that so little attention has been paid to these carbonophosphate minerals, for they are important from both the economic and scientific standpoints.

Evansite. $Al_3(OH)_6PO_4 \cdot (H_2O)_x$?—Evansite, a hydrous aluminum phosphate described by Forbes in 1864, is a typical amorphous mineral. It occurs as a colloform incrustation and greatly resembles allophane. The index of refraction determined on a specimen from Zelegnik, Hungary, is 1.483 ± 0.003.

Evansite has recently been described from two American localities (Goldburg, Idaho, and Columbiana, Alabama) by Schaller.[2]

Pitticite. $FeAsO_4 \cdot Fe_2O_3 \cdot (H_2O)_x$?—Pitticite is a dark-brown massive mineral resembling limonite. It is a basic ferric aresenate and often contains the sulfate radical. An artificial colloidal basic ferric arsenate has been described by Holmes and Rundfusz.[1]

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[1] *Corallogene Phosphat-Inseln Austral Oceanien und Ihre Produkte* (Lübeck, 1913), p. 54.

[2] *Bull. 490, U.S. Geol. Surv.*, 1911, p. 94.

I have examined specimens of pitticite from two localities, one on the west side of the South Merced River in Mariposa County, California, and the other at Sioux City, Iowa. At the first locality it is an oxidation product of arsenopyrite and at the second it occurs with limonite and aragonite.

Pitchblende $UO_2,UO_3,(H_2O)_x$ (Uraninite in part, nasturan).—The colloform or massive pitchblende seems to be the amorphous equivalent of isometric uraninite. Its water content is higher and its nitrogen and rare earth content lower than that of uraninite. It may also be distinguished by its lower specific gravity (6.5 to 8; uraninite is 9 or above).

Uraninite occurs in pegmatites while pitchblende occurs in metalliferous veins with sulfids.

(*Maskelynite*) ?—Maskelynite was first described by Tschermak from the Shergotty (India) meteorite. It is optically isotropic and in composition is very close to a plagioclase with equal molecular percentages of albite and anorthite. As the index of refraction is almost exactly the same as that of an artificial glass[2] of the composition Ab_1An_1, it is probably the amorphous equivalent of plagioclase (not necessarily a fused plagioclase) and not an isometric mineral.

Maskelynite is on the same footing as lechateliérite. They are the only glasses which have been regarded as minerals within recent years. They may be disposed of by considering them mineraloids rather than as definite minerals.

Malacon. $ZrSiO_4(H_2O)_x$? (cyrtolite, auerbachite, oerstedite, ostranite).—Malacon is the name given to a mineral from Hitterö, Norway, which has the form of zircon, but is softer and contains water. It is undoubtedly an alteration product and in all probability the amorphous equivalent of zircon. It deserves recognition as a distinct mineral, and Lacroix so regards it.

Malacon may be distinguished from zircon, not only by its isotropic character and water content, but also by its inferior hardness and specific gravity and its lower index refraction ($n = 1.826$

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[1] *Jour. Am. Chem. Soc.*, XXXVIII (October, 1916), 1970.

[2] Larsen, *Am. Jour. Sci.* (4), XXVIII (1909), 267.

Larsen). The other minerals mentioned above (cyrtolite, etc.) are probably synonyms of malacon.

Halloysite. $H_4Al_2Si_2O_9(H_2O)_x$ (myeline, indianaite, clayite, bole in part, kaolin in part).—It is generally recognized that some of the clays consist in whole or in part of amorphous aluminum silicates. Mellor[1] has proposed the name clayite for the amorphous constituent, but fortunately halloysite has priority.

Halloysite may be regarded as the amorphous equivalent of crystalline kaolinite, for it has the formula $H_4Al_2Si_2O_9+_x(H_2O.)$ In LeChatelier's experiments on halloysite the water given off below 250° C. varied within wide limits, while the water given off above this temperature was fairly constant and corresponded to that of kaolinite.

Myeline is an indurated clay from Rochlitz, Saxony, which is almost identical with kaolinite in chemical composition. I have examined a specimen from the type locality and find it to be essentially amorphous (there are patches of micro-crystalline material) with an index of refraction of 1.556 ± 0.001. Gagel[2] has described a non-crystalline myeline-like substance which occurs as an alteration product of trachydolerite at Canical, Madeira.

I have examined indianaite from St. Lawrence County, Indiana, which the published analyses show is a very pure halloysite, and find it to be an amorphous mineral with an index of refraction of 1.538 ± 0.002, which is less than that of kaolinite ($n=1.567-1.561$).

A clay from Morton, Minnesota, with imperfect pisolitic structure consists largely of an amorphous substance with an index of refraction of 1.557 ± 0.003, and hence may be referred to halloysite. This clay also contains some hydrargillite.

I have examined "kaolin" from Broken Hill, New South Wales, and find it to be amorphous with $n=1.548\pm0.002$. This must be halloysite.

The "isotropic kaolinite-like mineral" described by Larsen and Wells[3] from Wagon Wheel Gap, Colorado, has an index of refraction of 1.557 and a water content of 15.5 per cent, and hence should be referrred to halloysite.

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[1] *Trans. Eng. Cer. Soc.*, VIII (1908).

[2] *Central. f. Min., Geol., u. Pal.*, 1910, p. 225.

[3] *Proc. Nat. Acad. Sci.*, II (1916), 364.

Helmhacker[1] describes halloysite with a small botryoidal surface from Banat, Hungary. The Rochlitz myeline also shows colloform crusts in cavities.

From the available evidence it seems clear that halloysite is the amorphous equivalent of kaolinite. The recognition of this may help in a clearer understanding of the constitution of clays. The determination of the index refraction, which varies from 1.538 to 1.557, is probably a safer means of distinguishing halloysite from kaolinite than the absence of double refraction. The presence of aluminum hydrate in solid solution may, however, modify the index of refraction.

Allophane. $Al_2SiO_5(H_2O)_x$ (carolathine).—Allophane has long been recognized as one of the typical amorphous minerals. Its colloform shape, optical isotropism, and absence of cleavage and structure leave no doubt as to its amorphous character. The index of refraction of a specimen from Bedford, Indiana, is 1.473±0.003.

Whether schrötterite and collyrite should be considered synonyms of allophane is open to question.

Stevensite. $H_2Mg_3(SiO_3)_4 \cdot (H_2O)_x$ (talc in part, lucianite?).—An alteration product of pectolite found at several localities in New Jersey is probably the amorphous equivalent of crystalline talc. This substance was first described by Leeds[2] who used stevensite as a name for talc pseudomorphous after pectolite. Glenn[3] has recently studied this mineral, and his work proves that it should be considered a distinct mineral. Wherry made a microscopic examination and shows that it is isotropic with an index of refraction of about 1.50. Stevensite is also distinguished from talc by its lower specific gravity and higher water content.

Stevensite is probably not a monohydrate of talc, as Glenn suggests, but the water content is evidently variable and reaches over 19 per cent in the clay mentioned in the next paragraph.

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[1] *Min. u. petr. Mitth.*, II (1879), 232.

[2] *Am. Jour. Sci.* (3), VI (1873), 22–23.

[3] *American Mineralogist*, I (1916), 44–46.

Hilgard[1] has recently described, from a locality near the City of Mexico, a peculiar clay which consists largely of a hydrous magnesium silicate. This substance was named lucianite, but as it is a colloidal substance with specific gravity of 2.25 and is soluble in hydrochloric acid it is probably a synonym of stevensite.

Cornuite. $m\mathrm{CuO}\cdot n\mathrm{SiO_2}\cdot(\mathrm{H_2O})_x$ (chrysocolla in part).—In specimens of chrysocolla from a number of localities I have noted a glassy, green or bluish-green copper silicate which is the amorphous equivalent of chrysocolla. To this newly recognized mineral I wish to apply the name *cornuite* in honor of the late Dr. Felix Cornu, of Leoben, Austria, who was practically the first mineralogist to make a sharp distinction between crystalline minerals and their amorphous equivalents.

I have found this mineral on specimens from Globe, Arizona; Bisbee, Arizona; Ludwig, Nevada; Copper Mountain, Alaska, and Collahuasi, Chile. It is usually optically isotropic with n varying from 1.525 to 1.549, but sometimes has irregular, weak double refraction and wavy extinction. It is associated with crystalline chrysocolla and often appears in colloform bands within layers of colloform chrysocolla. It is more readily soluble in hydrochloric acid than chrysocolla and also somewhat softer.

The best specimens of cornuite in my possession are from the mine of the Alaska Consolidated Mining and Smelting Company at Copper Mountain, Prince of Wales Island, Alaska. It occurs as a beautiful bluish-green (Ridgway 42k), transparent, glassy, somewhat banded crust about 1 cm. thick associated with chrysocolla. The index of refraction is 1.549±0.001. I am indebted to my collegue, Dr. G. S. Bohart of the chemistry department, for the following analysis of the Copper Mountain cornuite:

		Ratios
CuO	=42.61	0.537
$\mathrm{Al_2O_3}$	= 0.31	0.004
$\mathrm{SiO_2}$	=34.13	0.566
$\mathrm{H_2O}$	=23.11	1.284

These figures are each the average of two closely agreeing values made upon carefully selected material free from the associated chrysocolla and all other impurities. The ratios seem to show an excess of both silica and water over that required for the usually accepted empirical formula (H_4CuSiO_5) for chrysocolla, which probably indicates that cornuite is a solid solution of cupric oxid, silica, and water.

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[1] *Proc. Nat. Acad. Sci.*, II (1916), 8–12.

Probert[1] describes a "jelly of the most beautiful shades of blue and green" with the following composition: $CuO = 47.46$; $SiO_2 = 21.20$; $H_2O = 28.05$; $CaO = 1.39$; $Al_2O_3 =$ tr., from the 200-foot level of Ray Central mine at Ray, Arizona. Here we evidently have cornuite in process of formation.

Chrysocolla is sometimes considered to be an amorphous mineral, but while chrysocolla shows colloidal structures it is microcrystalline (metacolloid), and recently Umpleby[2] has described crystallized chrysocolla from Mackay, Idaho, the indices of refraction of which are $n_\gamma = 1.57$ and $n_\alpha = 1.46$.

OTHER POSSIBLE VALID AMORPHOUS MINERAL SPECIES

The twenty-three amorphous minerals described in this paper are all believed to be well-established mineral species. Practically all of them are known from several localities and some of them are very common and widely distributed minerals. Although their properties vary somewhat, these minerals are fairly definite and can be recognized by careful work.

There are, however, as many more amorphous minerals which have been described or named, and some of these it may be possible to establish by study of suitable material. I have attempted to enumerate here some of the probable amorphous minerals.

Metastibnite, amorphous Sb_2S_3.
Jordisite, colloidal MoS_2.
Patronite, vanadium sulfid.
Ostwaldite (Buttermilcherz), colloidal AgCl.
Ehrenwerthite, colloidal $Fe_2O_3 \cdot H_2O$.
Amorphous equivalent of fischerite.
Schadeite, amorphous equivalent of plumbogumnite.
Palmerite, hydrous aluminum potassium phosphate.
Yukonite, hydrous calcium iron arsenate.

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[1] *Min. and Sci. Press*, CXII (1916), 898.

[2] *Jour. Wash. Acad. Sci.*, IV (1914), 181.

Gummite, alteration product of uraninite.
Glockerite, hydrous ferric sulfate.
Plumboniobite.
Amorphous equivalent of thorite.
Amorphous equivalent of allanite.
Amorphous equivalent of gadolinite.
Amorphous equivalent of yttrotantalite.
Amorphous equivalent of homilite.
Amorphous equivalent of yttrocrasite.
Amorphous equivalent of pyrophyllite.
Greenalite, hydrous ferrous silicate.
Yttrialite.
Neotocite.
Plombierite.
Geolyte (Bodenzeolith), amorphous equivalent of zeolites.
Pochite.

MINERALOIDS (HYDROCARBONS AND GLASSES)

In addition to the foregoing definite amorphous minerals there are several other classes of naturally occurring amorphous substances. I refer to the hydrocarbons and glasses. Shall they be considered as minerals or not? The answer depends upon our definition of the term mineral or mineral species. A mineral (species) is usually defined as a naturally occurring homogeneous substance of definite chemical composition. By common consent the term is limited to the naturally occurring substances, although the specific mineral name is often used for the corresponding artificial substance. No objection can be raised if the word synthetic or artificial is prefixed to the mineral name. In view of the discovery of solid solutions of a kind different from isomorphous mixtures in minerals, the definition given above must be modified so as to read "of more or less definite chemical composition," as suggested by Wherry.[1]

In the case of the hydrocarbons the principal objection against considering them minerals is on account of their organic character. While directly or indirectly the result of organic growth, they are on a somewhat different footing from ordinary plant products. They occur with other minerals in sedimentary rocks and are, in fact, fossil resins and fossil fuels. They are collected and studied by geologists.

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[1] *Ibid.*, pp. 111–14.

The hydrocarbons are by some mineralogists given full rank as minerals, by others omitted entirely, by still others treated in an appendix to minerals. The latter procedure seems to be the safest plan, for they are organic substances, and the typical minerals are certainly inorganic, yet on the other hand they deserve some recognition by the mineralogist. The mineralogist is often called upon to identify them, and they should be described from a mineralogical standpoint.

For these reasons I think the hydrocarbons may be included under Niedzwiedzki's term *mineraloid*.[1] As Niedzwiedzki used this term for all naturally occurring amorphous substances, this changes somewhat the original definition of mineraloid. Such substances as opal, cliachite, limonite, collophane, halloysite, etc., are definite enough to be called minerals even though they are amorphous. The term "mineraloid" seems appropriate for the less definite mineral-like substances.

And in the same category I would also place the natural glasses. As far as I know, glass is not given a place in any modern mineralogical treatise, although the older mineralogists described tachylyte and hyalomelane as mineral species. It is, however, included in some of the determinative tables of the rock-forming minerals found in textbooks on petrography, and for the same reason that it is included in these tables it may be treated as a mineraloid. Natural glass is a homogeneous substance to be identified the same as minerals in general.

Natural glass is, of course, varied in composition in comparison with the various types of igneous rocks, yet the average obsidian is probably not much more varied than some of the amorphous minerals. While glass is scarcely entitled to recognition as a mineral, there are arguments in favor of classifying it as a mineraloid. It may well receive a place in the appendixes of our books on mineralogy. This will call attention to its properties and will aid in its identification, which otherwise might be difficult for a beginner who had studied mineralogy but not petrography.

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[1] *Centralblatt f. Min., Geol., u. Pal.*, 1909, pp. 661–63.

Glass, like amorphous substances in general, is in part optically isotropic and in part birefringent. The birefringence is shown in many perlites, some varieties of which are veritable Prince Rupert's drops. Besides the chemical composition, the most important property of glass is its refractive index, which, as has been shown by Stark,[1] varies from about 1.485 for "acid" glasses with 75 per cent silica up to 1.67 for "basic" glasses with 40 per cent silica. Obsidian, perlite, pitchstone, etc., are petrographic terms, but glass as a whole may be treated as a mineraloid from the mineralogical standpoint. Lechateliérite and maskelynite are glasses which are fairly definite in chemical composition.

SUMMARY

Some of the naturally occurring amorphous substances are definite enough to be recognized as mineral species.

The amorphous equivalents of crystalline minerals should be treated as distinctive minerals and should have distinctive names.

About twenty of the more prominent and well-defined amorphous minerals are described and discussed. Most of these minerals are the amorphous equivalents of crystalline minerals.

New names are given to amorphous cadmium sulfid (xanthochroite) and amorphous copper silicate (cornuite) which correspond to sphalerite, greenockite, and chrysocolla respectively.

Arguments are advanced for treating the natural hydrocarbons and natural glasses as mineraloids.

[1] *Min. u. Petr. Mitth.*, XXIII (1904), 536–50.